Appendix H5

Modeling Deposition of Contaminants Resuspended During TRA Warm Waste Pond Remediation

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Appendix H5

Modeling Deposition of Contaminants Resuspended during TRA Warm Waste Pond Remediation

H5-1. INTRODUCTION

This report documents the results of modeling the release and deposition onto soil of selected contaminants from pond sediments during remediation of the Test Reactor Area (TRA) Warm Waste Ponds. The results will be used to support an ecological risk assessment for Operational Unit 10-04.

There are three cells associated with the TRA Warm Waste Ponds area. They are the 1952 Cell, the 1957 Cell, and the 1964 Cell. The Cells are located outside the southeast corner of the TRA perimeter fence (Figure H5-1). The Warm Waste Ponds was remediated in 1993 and was replaced by a lined evaporation pond.

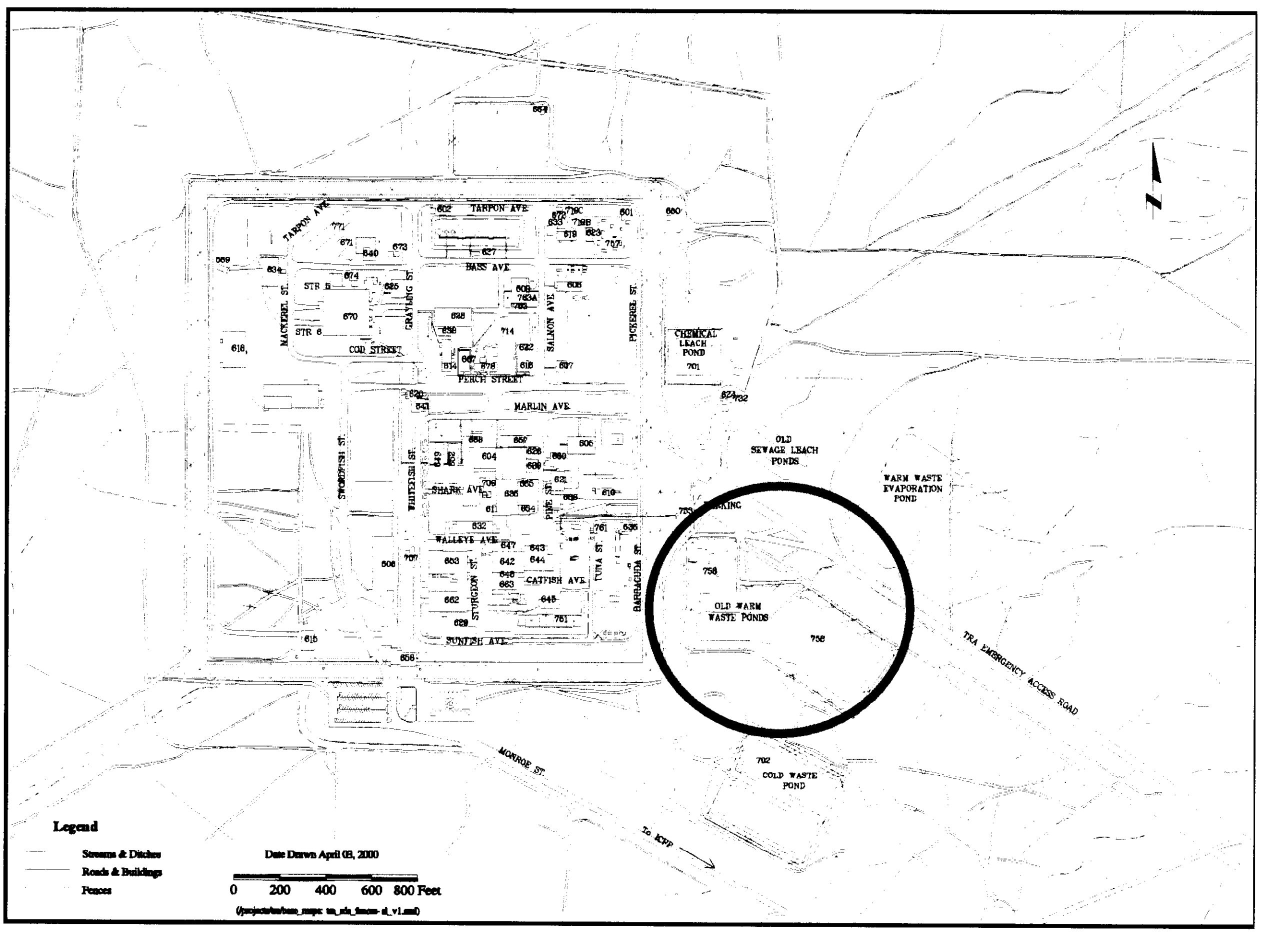

Figure H5-1. TRA facility map showing the warm waste ponds circled in red.

H5-2. CONCEPTUAL MODEL

H5-2.1 Selection of Resuspension Process

Resuspension of contaminated sediment particles can be wind-driven or mechanical. Wind-driven resuspension was possible at the warm waste ponds whenever portions of sediment were exposed to air, became dry, and were subject to movement by wind. Periods of sediment exposure occurred during routine operation of the warm waste ponds when liquid effluent discharges from TRA operations were exceeded by infiltration into surficial sediments. Sediments were also exposed after the ponds were no longer in use prior to remediation in October of 1993. However, the largest resuspension event probably occurred during remediation activities, when the sediments were mechanically disturbed.

The conclusion that mechanical resuspension probably exceeded wind-driven resuspension was made using the following logic. Mechanical resuspension rates have been measured to be about two orders of magnitude greater than wind-resuspension rates with wind speeds of 2 to 9 mph (Healy 1980). Thus, a month of mechanical disturbance of soil can result in a release of contaminants that is about ten times greater than that released during an entire year of wind-resuspension of undisturbed soil at the same site. In addition, a greater volume of sediments were exposed to the wind during remediation than is normally exposed during wind-driven resuspension. Most of the contaminants disposed into the ponds were concentrated in the top two to four feet of sediments beneath the ponds (Hull 1989). During remediation, the top three feet of sediments were excavated and moved. Conversely, wind-driven resuspension of soil particles occurs in the top layer, typically identified as the top millimeter or less (Healy 1980). Finally, the resuspension rate depends not only on the wind speed, but on the area and nature of the soils (particularly moisture content and particle size). The sediment surface exposed during periods of pond dryness was probably resistant to wind resuspension. Hull (1989) notes the infiltration capacity of the pond sediments decreased over time due to the buildup of chemical precipitates and algae (Hull 1989). Sediment consolidation would have resulted in a lower resuspension rate. Conversely, during remediation, mechanical disturbance probably resulted in a larger quantity of small particle aggregates.

H5-2.2 Selection of Remediation Activities to be Modeled

The remediation consisted of the following activities (DOE 1994), following the timeline shown in Figure H5-2:

1. **Initial scrapedown** (October 23–October 27, 1993). A bulldozer was used to scrape approximately six inches of radiologically-contaminated soil from the surface of the exclusion zone around the south, east, and west perimeters of the three cells. Approximately 1,500 cubic yards of soil were pushed to the nearest of the three cells to minimize movement of the contaminated material.

2. **Excavation of the 1964 Cell** (October 29–November 12, 1993). Two dozers were used to remove three feet of contaminated soil from the cell sidewalls and to push the material into the bottom of the cell. Front-end loaders were used to move the soil to the 1952 cell. Because the pond sediments were consolidated, the bottom of the 1964 Cell was ripped with a bulldozer equipped with a ripper shank. Three feet of the bottom soil was then excavated, proceeding from the south side to the north side. The excavated soil was then moved to the 1952 Cell. After cell excavation, a civil survey determined that one additional foot of soil had to be removed from the sidewalls to ensure that three feet of soil had been excavated. After removal of the additional foot of sidewall soil, the excavation limits were reached.

3. **Filling of the 1952 Cell** (October 29–December 6, 1993). Following excavation of the 1964 Cell, the 1964 Cell sediments were initially transferred by front-end loader to the east edge of the 1952 Cell. The sediments were used to construct a ramp to the bottom of the 1952 Cell. Earth-moving equipment entered the 1952 Cell via the ramp and spread the 1964 Cell sediments over the bottom of the 1952 Cell in 12-inch loose lifts. After the ramp was completed, it was observed that the 1952 Cell could be filled more efficiently by continually pushing the 1964 Cell material into the cell from the east side. All excavated 1964 Cell materials were deposited into the 1952 Cell by November 19, 1993. Materials from the existing waste stockpiles were then placed over the 1964 Cell sediments and mounded with bulldozers to achieve an approximate two-percent grade.

4. **1952 Cell Cover** (December 11–December 20, 1993). A one-foot clean soil cover was placed over the 1964 Cell sediments and waste stockpile material in the 1952 cell. The cover material was obtained from a clean fill stockpile (the "south stockpile") located immediately south of the 1952 and 1964 Cells.

5. **1964 Cell Backfill** (December 9, 1993–January 19, 1994). The 1964 Cell was filled with clean backfill from the south stockpile.

6. **1957 Cell Activities** (November–December 1993). An as low as reasonably achievable (ALARA) Committee Review conducted on November 4, 1993, indicated that radiation levels on the north and east sidewalls of the 1957 Cell were too high to allow field personnel to work within the cell. Thus, these sidewalls were covered with waste stockpile material to reduce the radiation field prior to excavation activities. Later, during backfilling of the 1952 Cell and several weeks after the north and east sidewalls of the 1957 Cell were covered, the remaining two sidewalls were excavated. Bulldozers were used to push the sediments from the south and west sidewalls into the bottom of the cell, where approximately 500 cubic yards of sediments were spread evenly over the bottom of the cell. A subsequent civil survey indicated that excavation limit (two feet) specified in the remedial design had not been met. Therefore, additional soil was removed from the sidewalls.

7. **Final Scrapedown** (December 3–11, 1994). A scraper was used to remove approximately six inches of soil from the waste stockpile area east of the 1952 Cell. The material was placed in the 1952 Cell prior to the construction of the 1952 Cell cover.

Of the seven activities listed above, it is apparent that the excavation of the 1964 Cell and the filling of the 1952 Cell with the excavated material resulted in the greatest suspension of contaminated material followed by dispersion and deposition of those contaminants outside the pond area. For this reason, the modeling of dispersion and deposition of selected contaminants from the remedial action focused on the excavation of the 1964 Cell and the placement of the contaminated sediment in the 1952 Cell.

H5-2.3 Final Conceptual Model

Based on the observations made above, the conceptual model shown in Figure H5-3 was developed. During the excavation of the 1964 Cell and the filling of the 1952 Cell, contaminated sediment particles become airborne. The resuspension rate is dependent on particle size, wind speed and moisture content of the sediment. Resuspended particles are then dispersed and deposited in the environment, depending on wind speed, other meteorological conditions, and particle size. Once deposited on soil surfaces, the contaminants are subject to radioactive decay (if radioactive), and leaching into subsurface soils. The leach rate is dependent primarily on the infiltration rate and the contaminant-specific distribution coefficient, $K_{d,}$.

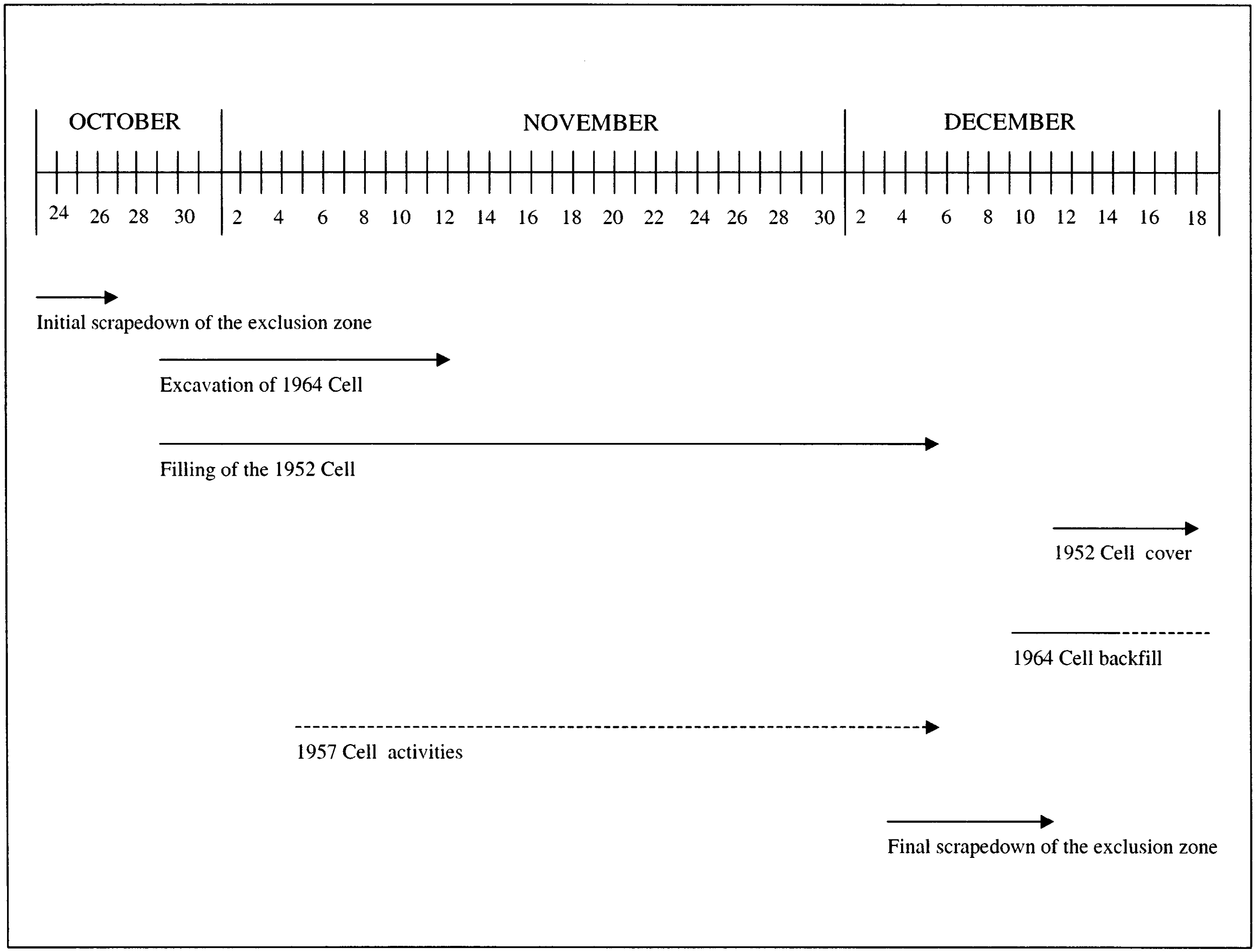

Figure H5-2. Timeline of TRA warm waste pond remediation activities.

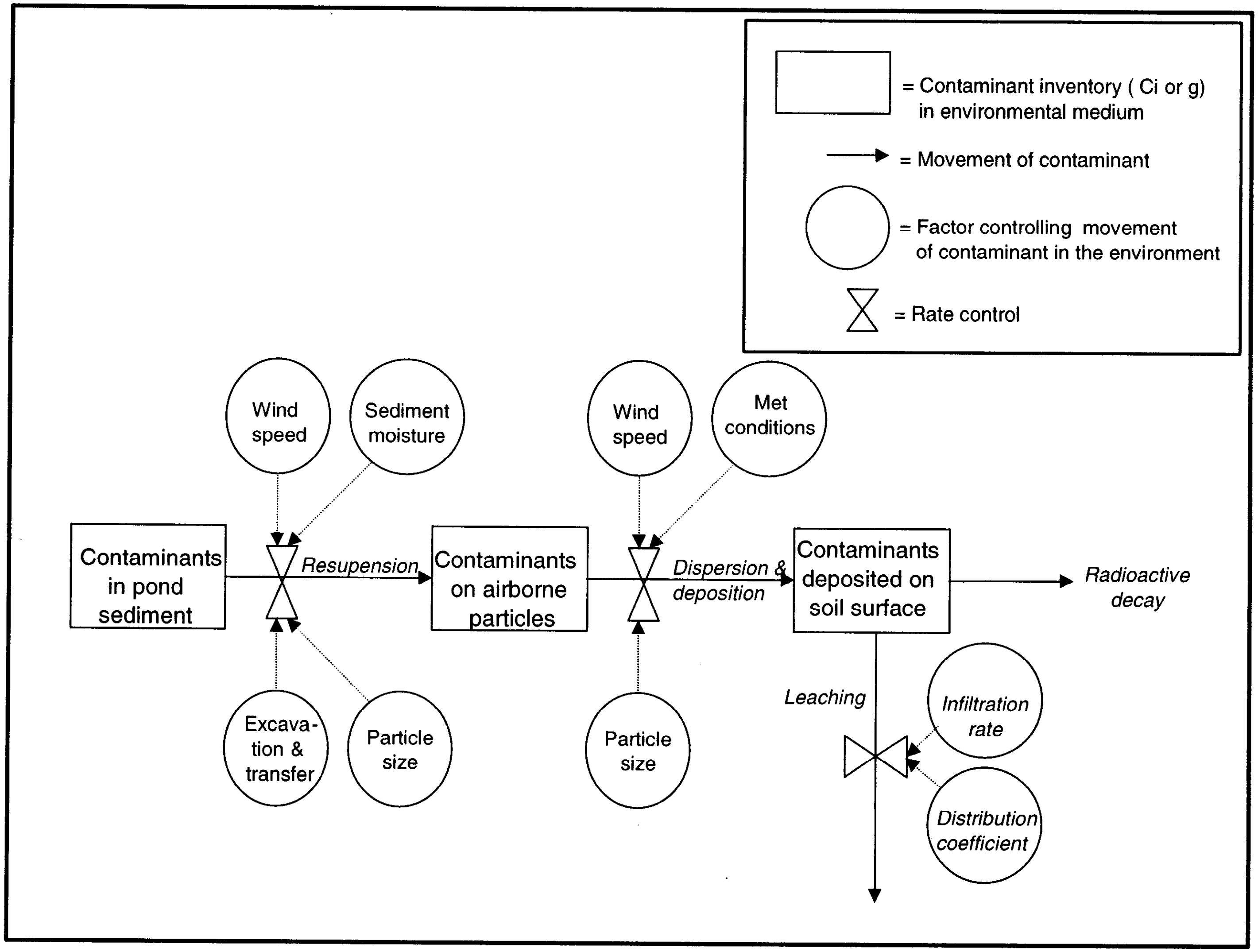

Figure H5-3. Conceptual model of resuspension of contaminated TRA warm waste pond sediments during excavation and transfer of the 1964 pond sediments.

H5-3. MODELING APPROACH AND METHODS

The general modeling approach used was to first calculate the particulate emissions during the excavation of sediment from the 1964 Cell and transfer into the 1952 cell, using an appropriate EPA algorithm, and then to model subsequent dispersion and deposition of the sediment particles onto soil, using an Environmental Protection Agency (EPA) atmospheric dispersion code. Finally, concentrations of specific contaminants measured in sediment samples were used to estimate how much contamination was deposited on surface soil outside the ponds via particulate emissions.

H5-3.1 Particulate Emissions

The majority of contamination was most likely released during the excavation of the 1964 Cell and subsequent filling of the 1952 Cell with contaminated sediment from the 1964 Cell. Realistic modeling of these activities would treat the source term as a series of point sources that represent individual lifts of sediment from the bottom of the 1964 cell and transfers of the material to the bottom of the 1952 Cell. This modeling approach would be extremely complex and tedious, and would require more information about the remediation activities than is currently unavailable.

For this reason, it was decided that a more conservative, though less realistic, approach should be taken. The modeling approach used was to treat the 1964 Cell as an area source from which contaminated particulates were continuously released during removal and filling activities. This approach is conservative and encompasses the true source term.

The EPA document entitled "Hazardous Waste TSDF Fugitive Particulate Matter Air Emissions Guidance Document" (Cowherd et al. 1989) provides several approaches to modeling the release of particulates from erosion of soil surfaces. The most appropriate algorithm for estimating emissions during removal of surface materials is as follows:

$$e = k(0.0032)\frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad (lb/ton) \tag{1}$$

where:

e = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed, (mph)

M = material moisture content, %

This equation is recommended for estimating emissions from transfer operations (batch or continuous drop) involving aggregate materials. Examples of batch drop operations include truck dumping or loading a truck with a front-end loader. Thus, this algorithm best models the picking up and dropping the 1964 Cell sediment with the front-end loader, and pushing the material into the 1952 Cell.

The particle size multiplier *k* in equation 1 varies with aerodynamic particle diameter as shown in Table H5-1. The particle size multiplier of 0.74 for suspendible particles (< 30 μm) was selected.

Table H5-1. Aerodynamic Particle Size Multiplier, k.

	Particle Size				
	< 30 μm	< 15 μm	< 10 μm	< 5 μm	< 2.5 μm
K	0.74	0.48	0.35	0.2	0.11

The material moisture content used during excavation and filling activities was presumed to be 9.3% (DOE 1993b). This assumed that the area was moistened above baseline moisture levels to suppress dust.

Hourly wind speed data measured by the National Oceanic and Atmospheric Administration (NOAA) at the Central Facilities Area (Grid III) during this time period were used to estimate particulate emission factors for each hour that sediment was moved. A search of the Environmental Restoration Optical Imaging System (http://erois.inel.gov/) yielded a record of earthmoving activities at the Warm Waste Ponds during the remediation period. The document, entitled "Warm Waste Ponds Wind Speed Surveillance Record" (EROIS #13747), contains a column in which the Health and Safety Officer marked the 15-minute time periods when earthmoving operations occurred. It was assumed that equation (1) was applicable to only those time periods during earthmoving operations. If the period of time spent in earthmoving operations was less than one full hour, it was conservatively assumed that the operation was sustained during the hour. During periods of inactivity, it was assumed that dust suppression activities inhibited resuspension.

The emission factor (lb/ton) was converted to emission rates (g/s/m^2) for use as a source file in the dispersion and deposition computer code, ISCST3. The hourly emission rates (g/s) were divided by the area of the 1964 Cell (10826.2 m^2), as determined from the geographical information system (GIS) figure (Figure H5-1).

The meteorological data, emission factors, and emission rates may be found in the Microsoft® Excel workbook entitled "Emission Rates". A hard copy of the workbook may be found in Appendix A.

H5-3.2 Dispersion and Deposition of Contaminated Materials

The Industrial Source Complex Short-Term code, Version 3, (ISCST3, dated 99155) was selected to model the dispersion and deposition of contaminated particulates during the excavation and filling activities. ISCST3 is an EPA-recommended, steady-state gaussian plume model used to assess pollutant concentrations from a number of sources associated with an industrial complex or remediation activity.

The ISCST3 model was set up using the following parameters:

1. The 1964 Cell was modeled as an area source, with the dimensions of 84.4 m × 133.1 m, with its northwest corner set at an angle of 124.4° from true north. The northwest corner of the Cell is located at universal transverse mercator (UTM) coordinates of 341350 m east and 482793 m north.

2. An hourly, area, source emission file (TRApond.prn) was created, based on the emission rates shown in Appendix A.

3. The meteorological file used was the 1993 Grid III file prepared by NOAA for the period from October 29, 1993, through November 19, 1993.

Table H5-2. Particle Data Used For Deposition Calculations.

Particle Aerodynamic Diameter (μm)	Mass Fraction[a]	Particle Density (g/cm^3)[b]
30	0.2	2.28
15	0.2	2.28
10	0.2	2.28
5	0.2	2.28
2.5	0.2	2.28

a. Particle size categories were assumed to be evenly distributed, since measured data are lacking.
b. Specific gravity of sediment size fraction < 75 μm (Beller and Bessent 1991).

4. The dry deposition option was used since no rainfall occurred during this period.

5. Particle data used for deposition calculations are as follows:

6. A rectangular receptor grid was used that contains an array of 50 × 50 points spaced 25 m apart. The grid encompasses the 1964 Cell at its center.

The model input file (ponds.in) may be found in Appendix B. The model output is the concentration of contaminated particles ($\mu g/m^2$) deposited at each receptor grid node during the excavation and filling period. The ISCST3 output may be found in the ASCII file entitled "PONDSC.out". The results were converted from text to data format in the Excel workbook entitled "ISCST output.xls", which is attached as Appendix C. The ISCST3 output (× 10^6 g particles/m^2) was converted to volumetric concentration (g particles/m^3), assuming that the deposition was limited to the first two inches of surface soil, as discussed in the following section.

H5-3.3 Concentration of Contaminants in Soil

H5-3.3.1 Radioactive Decay and Leaching of Contaminants

Modelers typically assume that the active deposition layer, which is also subject to resuspension, ranges from 1mm to 1 cm in depth. However, if sufficient time has elapsed, contaminant decay and infiltration into deeper soil layers can occur so that little of the deposited contaminant remains in the surface layer. This aspect was investigated using the simple compartment model program, BOXRAD (Rood 1995), which adapts the solution technique of Birchall (1986). BOXRAD calculates loss from compartments using first order kinetics. The conceptual model used is shown in Figure H5-3. Although most the contamination probably resides in the top centimeter, the uppermost surface soil compartment was assumed to be five-cm (two-in.) thick. This soil thickness was used because past soil studies in this area by the Department of Energy (DOE) Radiological Sciences and Environmental Laboratory (RESL) involved collecting soil from 0-5 cm (two-in.) (Jessmore et al. 1994). This allows for more meaningful comparison of the modeled results with measured values.

Values for leach rate and radioactive decay constants, as well as assumptions used to estimate these parameter values, are included in the Excel workbook entitled "Leach constant.xls" and are presented in Table H5-3.

Results of the BOXRAD calculations for the first seven years (1993–2000) following deposition, are shown in Figures H5-4 through H5-7. The model predicts that, with the exception of chromium, contaminants will remain primarily in the first two inches of soil. However, 90% of the chromium is retained in the first six inches of soil. Chromium appears to leach down at a more rapid rate than the other contaminants because the distribution coefficient used to partition the contamination between the water and solid phases in soil is very low. The distribution coefficient, which is typically used for groundwater models, may not realistically represent the leaching of chromium through surface soil (Magnusen 2000).

H5-3.3.2 Conversion of Deposited Particulate Concentrations to Contaminant Concentrations in Soil

The deposited particulate concentrations (g/m^2) calculated by ISCST3 were converted to contaminant concentrations (pCi/g for radionuclides or µg/g for chromium) by first dividing the ISCST3 results by the soil depth of 0.0508 m (2 inches), as discussed in the previous section. The results, g/m^3, were then transformed to current contaminant concentrations in soil using the following algorithm:

$$C_{soil} = \frac{C_{sed}}{\rho_{soil}} \times D_{part} \times f_r \qquad (2)$$

where

C_{soil} = Concentration of contaminant in soil (pCi/g or µg/g) seven years following TRA Warm Waste Pond remediation

C_{sed} = Concentration of contaminant in sediment (pCi/g or µg/g)

ρ_{soil} = Density of soil (g/m^3)

D_{part} = Concentration of sediment particles deposited on upper 2 inches of surface soil (g/m^3)

fr = fraction of contaminant remaining in upper 2 inches of soil after seven years of radioactive decay and leaching (1990-2000)(BOXRAD results).

Table H5-3. Leach Rates Used in the BOXRAD Calculations.

	Infiltration rate [a,b]	Vol. Water content [c]	Soil density [d]	Distribution coeff. [c]	Depth of soil layer		Leach rate
Contaminant	P (cm/yr)	θ (mL/cm ^{3})	ρ (g/cm ^{3})	K_d (mL/g)	d (cm)	d (in)	λ (yr^{-1})
Chromium	1	0.3	1.5	1.2	5.08	2	0.09374
Cobalt	1	0.3	1.5	10	5.08	2	0.01287
Cesium	1	0.3	1.5	500	5.08	2	0.00026
Strontium	1	0.3	1.5	24	5.08	2	0.00542

a. Cecil, L. D., J. R. Pittman, T. M. Beasley, R. L. Michel, P. W. Kubik, P. Sharma, U. Fehn, and H. Gove, 1992, "Water Infiltration Rates in the Unsaturated Zone at the Idaho National Engineering Laboratory Estimated from Chlorine-36 and Tritium Profiles, and Neutron Logging," in Proceedings of the 7th International Symposium on Water-Rock Interaction - WRI-7, Y. K. Kharaka and A. S. Meest (eds.), Park City, UT.
b. Magnusen, Swenn. Personal communication. March 18, 2000. "The measured rates, from a variety of natural tracer and neutron monitoring techniques ranged from 0.36 to 1.1 cm/year. This was for a vegetated, undisturbed site w/ slightly elevated topography relative to surroundings.
For our purposes, 'our' being any modeling study I have been involved in for Waste Management or Environmental Restoration, use a value of 1 cm/year out of DeWayne's measured range for background infiltration rates."
c. DOE, 1993a, Track 2 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL. Draft. DOE/ID-10389.
d. Maheras, S.J. et al., 1994, Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment. EGG-WM-8773, May 1994.

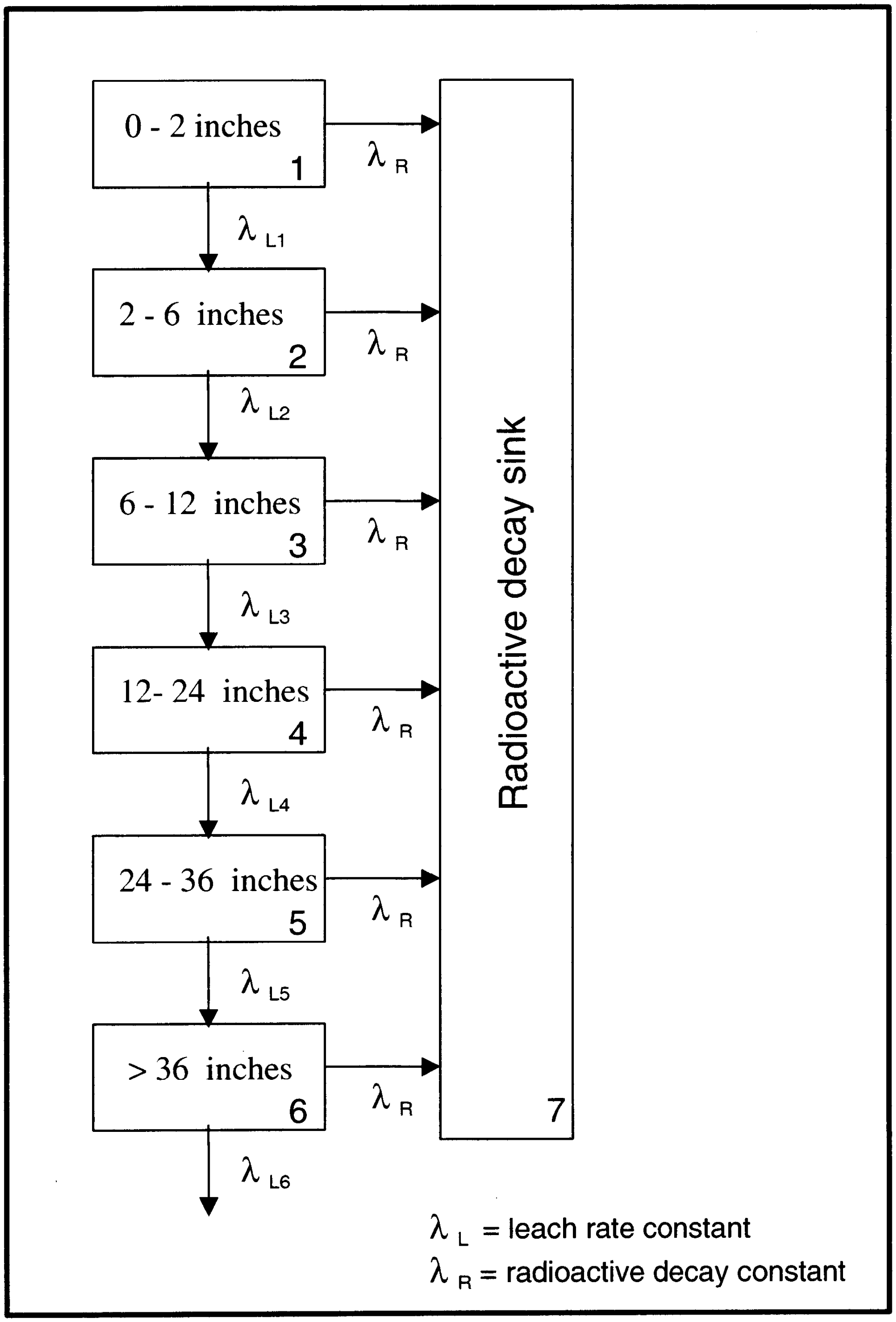

Figure H5-3. Conceptual model for BOXRAD problems.

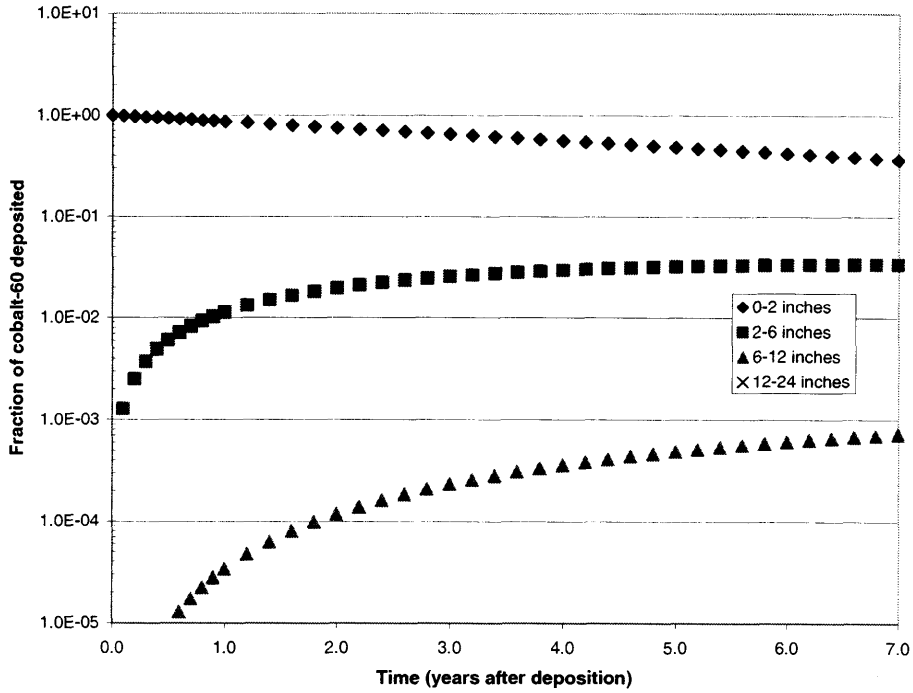

Figure H5-4. Fraction of cobalt-60 remaining in surface soil compartments over a seven-year period (1993–1997), as calculated using BOXRAD.

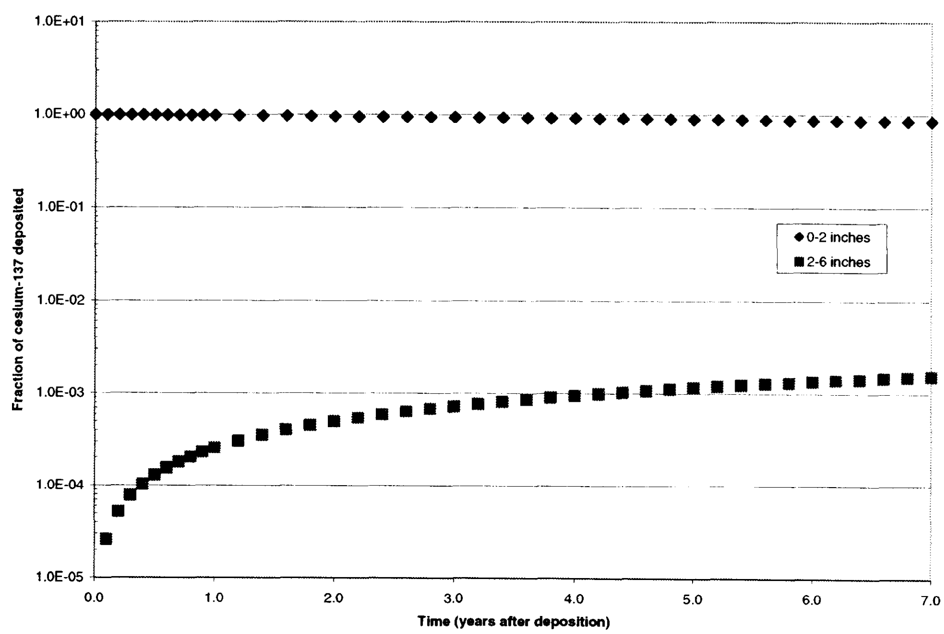

Figure H5-5. Fraction of cesium-137 remaining in surface soil compartments over a seven-year period (1993–2000), as calculated using BOXRAD.

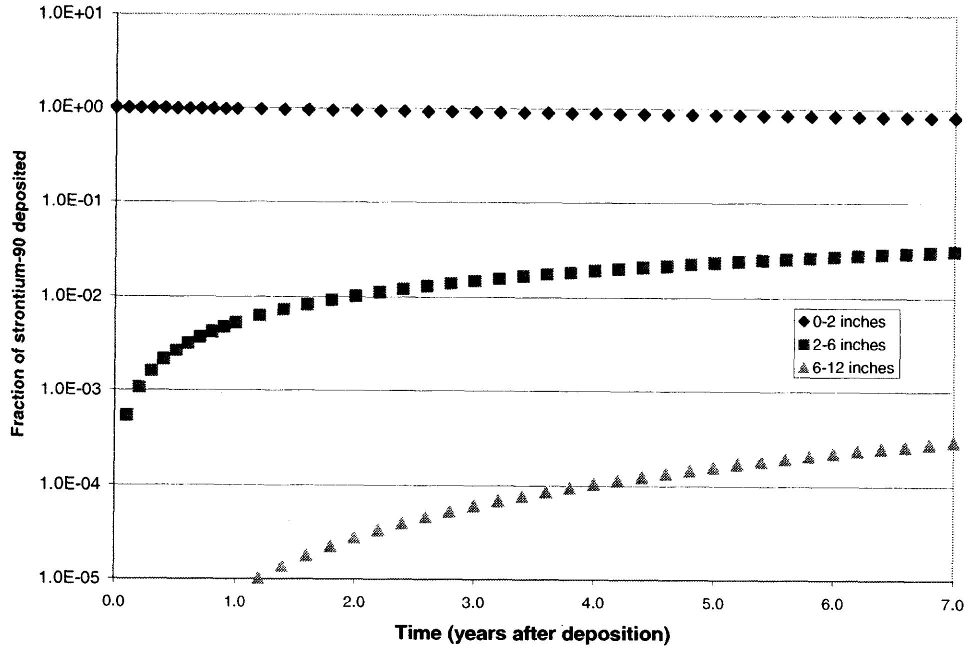

Figure H5-6. Fraction of strontium-90 remaining in surface soil compartments over a seven-year period (1993–2000), as calculated using BOXRAD.

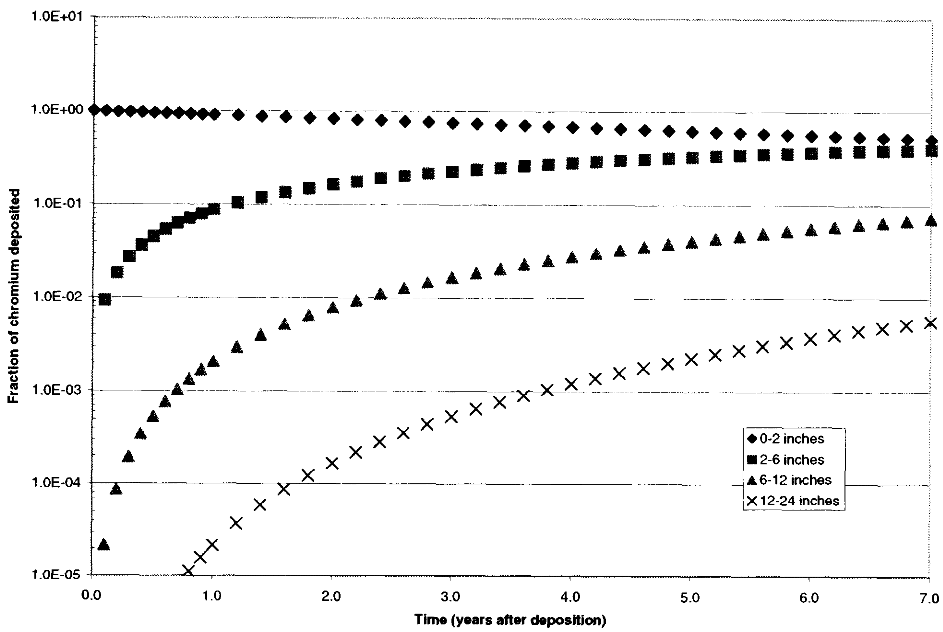

Figure H5-7. Fraction of chromium remaining in surface soil compartments over a seven-year period (1993-2000), as calculated using BOXRAD.

The contaminant concentrations were measured several times in the 1964 Cell sediments prior to remediation. However, the most conservative and recent data, found in Beller and Bessent (1991), were used and are presented in Table H5-3. This study was unique in that the concentrations of ^{60}Co and ^{137}Cs in the smallest sediment size fraction sieved (<600 μm) were measured. This fraction more realistically reflects the suspendable material (<75 μm) deposited on soil. Unfortunately, the concentrations of Cr and ^{90}Sr were not measured in the different sediment size fractions. The concentrations shown in Table H5-3 were not adjusted for radioactive decay from 1991 to 1993.

The density of soil used was 1.5 g/cm^3, which was used in the Radioactive Waste Management Complex (RWMC) low-level waste (LLW) radiological performance assessment (Rood 1994).

The concentration of sediment particles deposited on upper two inches of surface soil (g/m^3) are the ISCST3 results by the soil depth of 0.0508 m (two inches), as presented in Appendix C.

The fraction of contaminant remaining in the upper two inches of soil in the year 2000 was estimated using the BOXRAD computer code output (Figures H5-4 through H5-7).

Table H5-3. Contaminant Concentrations in Sediment.

Contaminant	Average Concentration (1993)
^{60}Co	26088 pCi/g[a]
^{137}Cs	47082 pCi/g[a]
^{90}Sr	2040 pCi/g
Cr	4536 μg/g

a. Average concentration in pan (<600 μm) fraction.

H5-4. RESULTS AND CONCLUSIONS

H5-4.1 Modeled Results

The results of the ISCST3 model runs and the estimated concentrations of contaminants deposited on soil are documented in the EXCEL workbook entitled "ISCST output.xls". Each result is associated with a specific UTM coordinate. The results are visually presented in Figures H5-8 through H5-12. Figures H5-8 through H5-11 show the contaminant concentrations in the area modeled (a 1250-m × 1250-m region) in detail. Figure H5-12 shows ^{137}Cs concentrations in the modeled area with respect to a larger area that includes the TRA and Idaho Nuclear Technology and Engineering Center (INTEC) facilities.

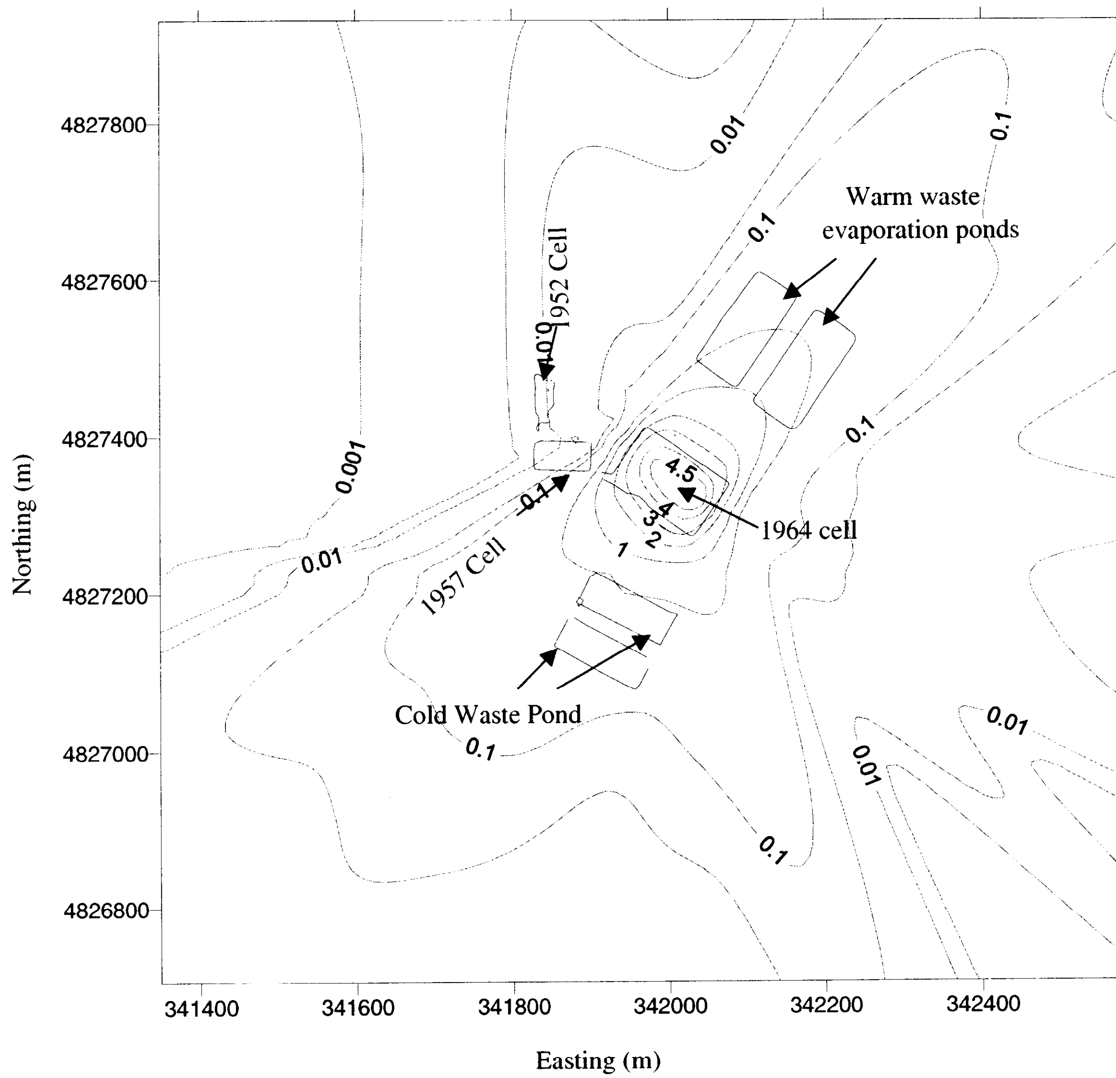

Figure H5-8. Estimated concentrations (pCi/g) of ^{60}Co deposited on surface soil (0–2 inches) outside the TRA Warm Waste Ponds (includes radioactive decay to the year 2000).

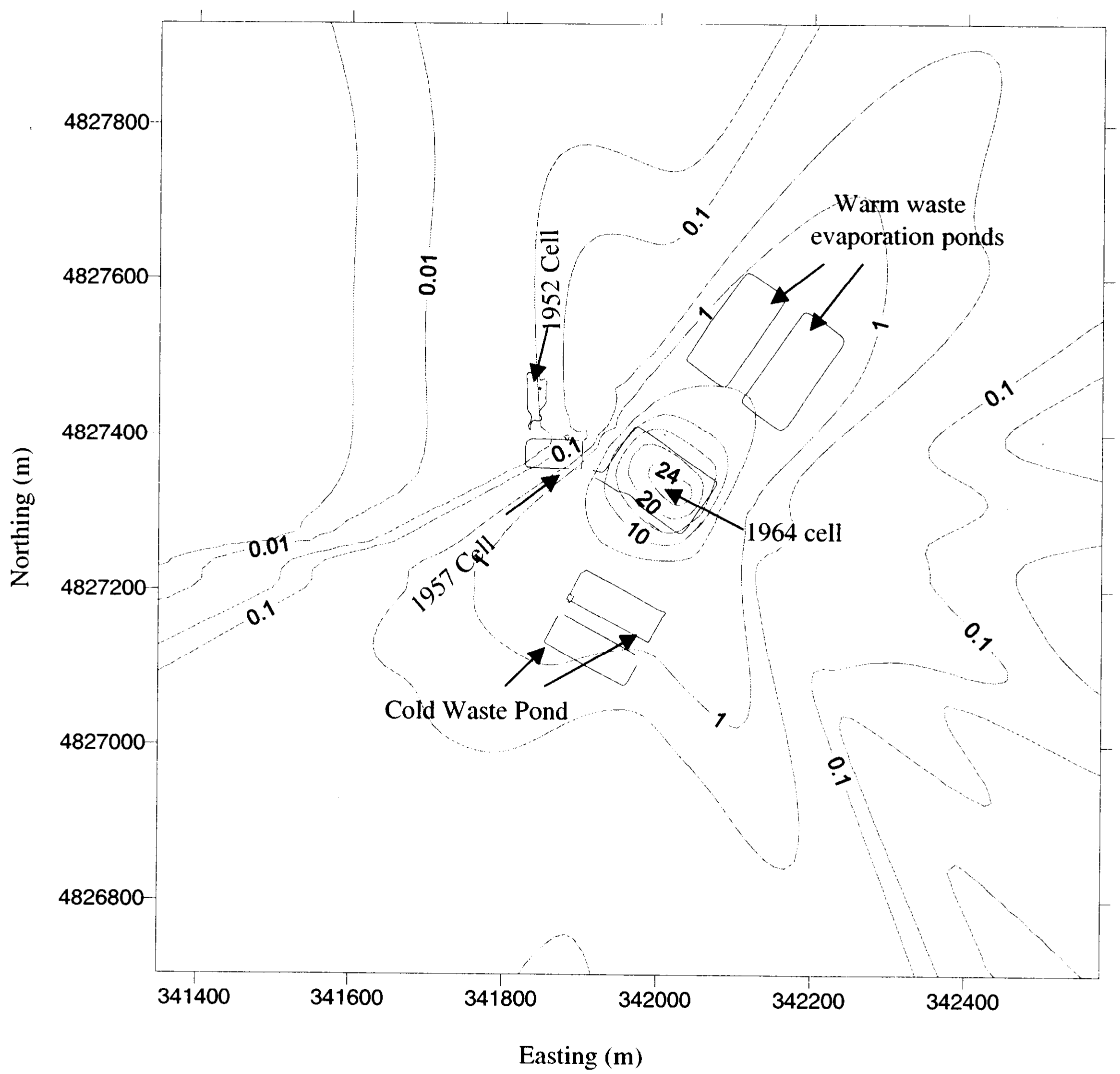

Figure H5-9. Estimated concentrations (pCi/g) of ^{137}Cs deposited on surface soil (0–2 inches) outside the TRA Warm Waste Ponds (includes radioactive decay to the year 2000).

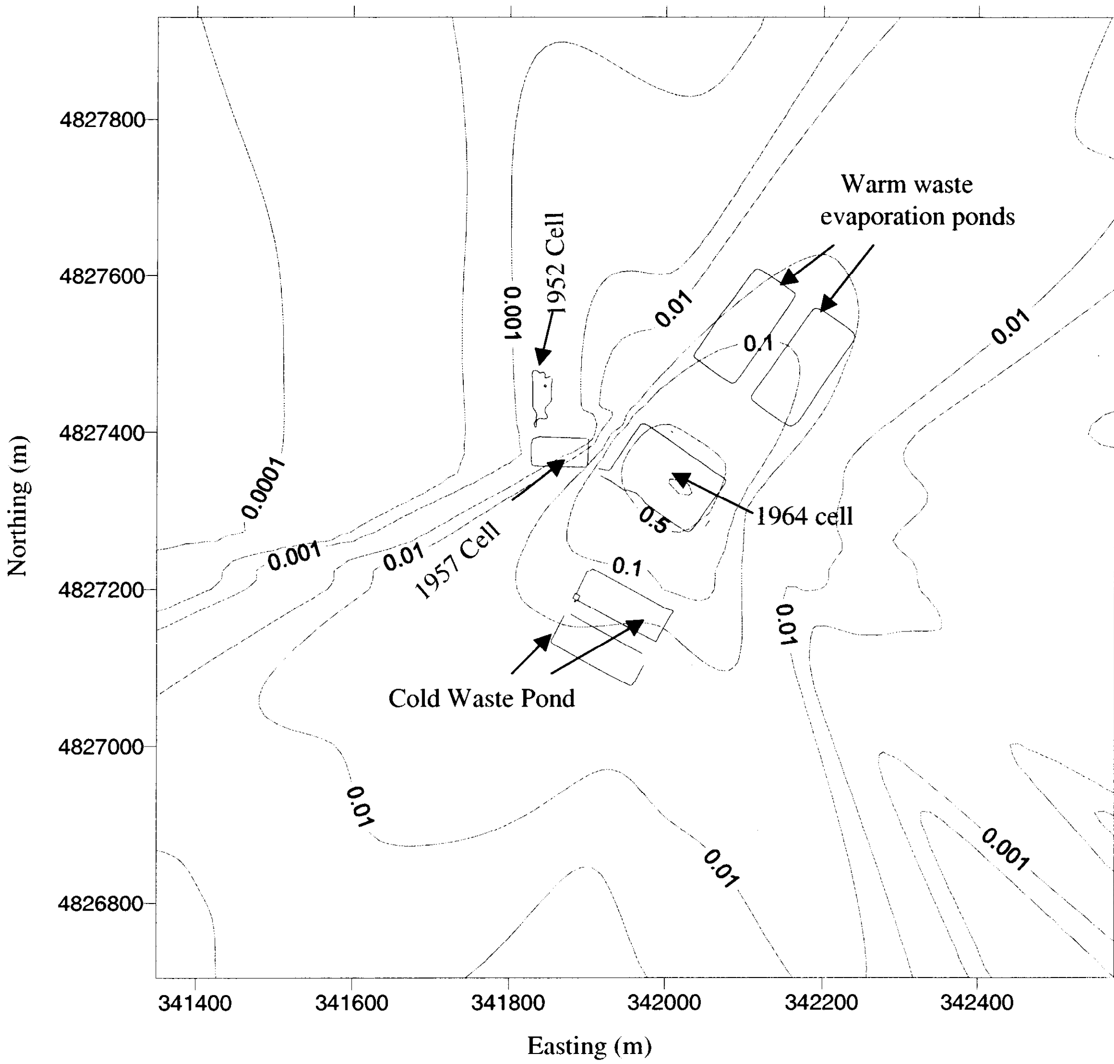

Figure H5-10. Estimated concentrations (pCi/g) of ^{90}Sr deposited on surface soil (0–2 inches) outside the TRA Warm Waste Ponds (includes radioactive decay to the year 2000).

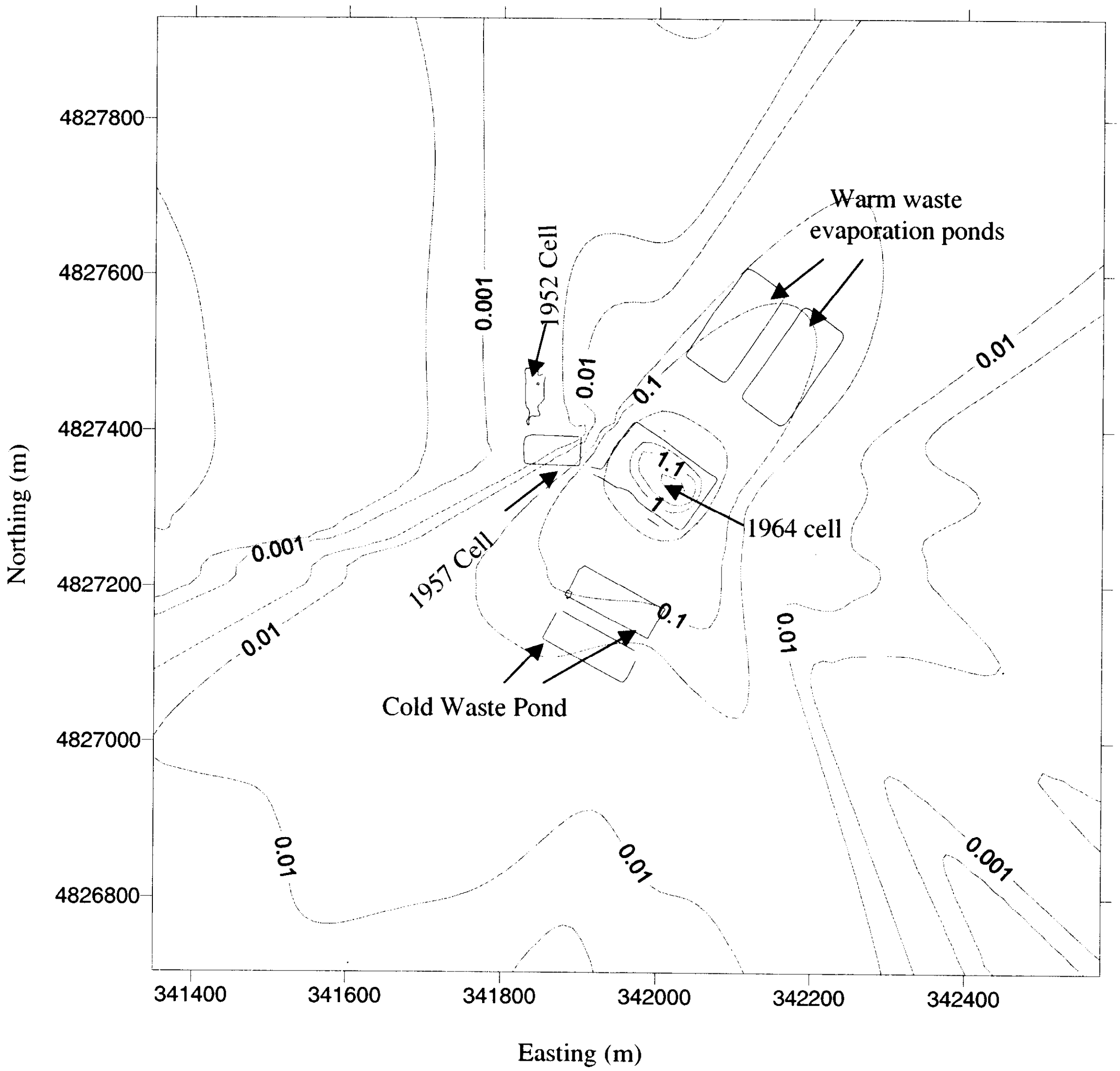

Figure H5-11. Estimated concentrations (μg/g) of Cr deposited on surface soil (0–2 inches) outside the TRA Warm Waste Ponds.

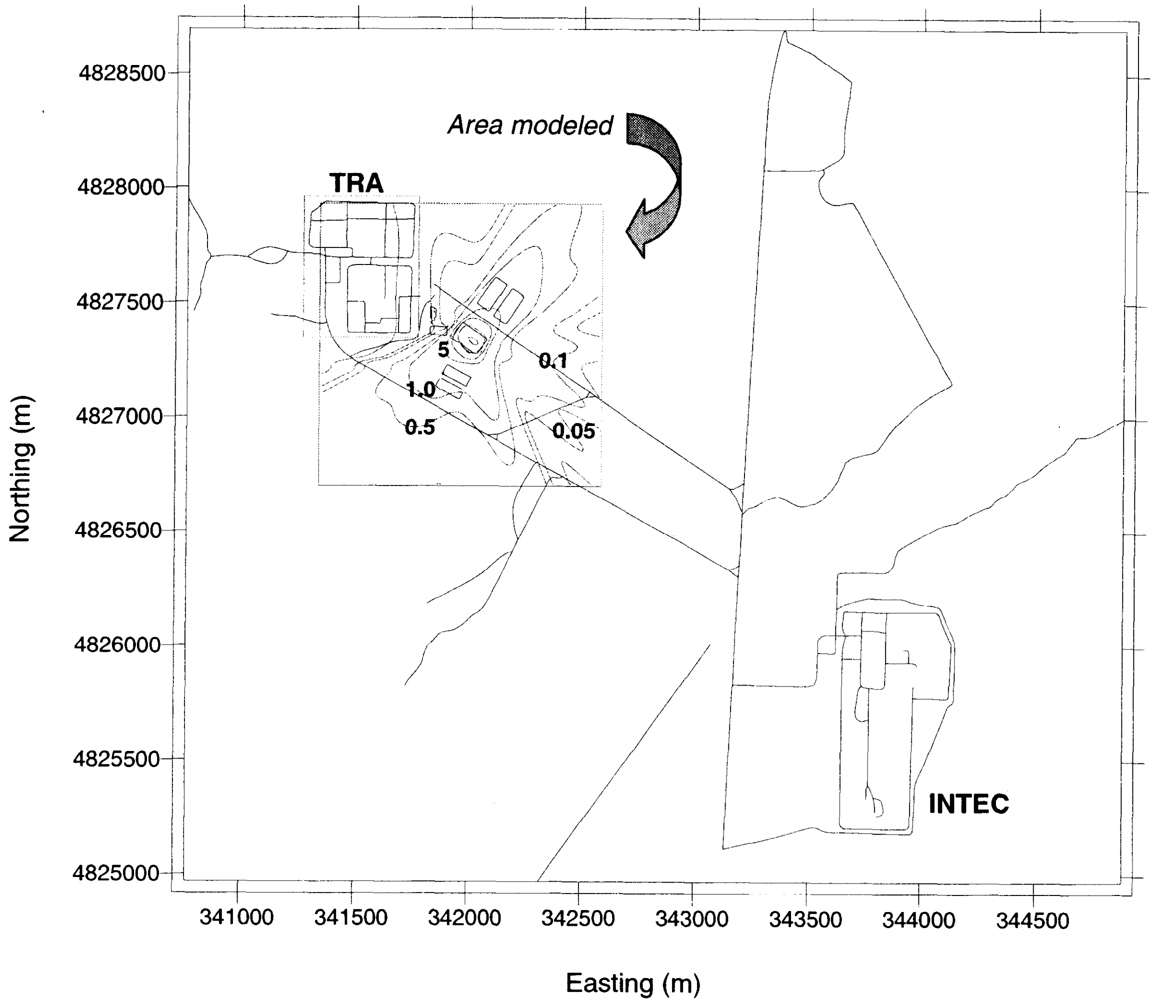

Figure H5-12. The modeled area with respect to the TRA and INTEC facilities.

The isopleths shown in the modeled area are for ^{137}Cs concentrations (pCi/g) (Figure H5-9).

H5-4.2 Comparison of Modeled Results with Measured Results

H5-4.2.1 Routine RESL and EMP Measurements

Measurements of radionuclides in soil have been made routinely in the vicinity of TRA. The DOE Radiological and Environmental Sciences Laboratory (RESL) established a routine soil sampling program outside individual Idaho National Engineering Laboratory (INEEL) facilities, including the TRA, in the early 1970s. In 1976, a rotating seven-year schedule for sampling outside of all INEL facilities was established. The last soil samples collected outside TRA and analyzed by RESL for radioactivity were obtained in 1990, three years prior to the warm waste pond remediation, at the locations shown in Figure H5-13.

In 1997, four years after warm waste pond remediation, the Lockheed Martin Idaho Technologies Company (LMITCO) Environmental Surveillance Program continued the RESL sampling program. The soil sampling locations adapted by LMITCO are shown in Figure H5-14 (LMITCO 1999).

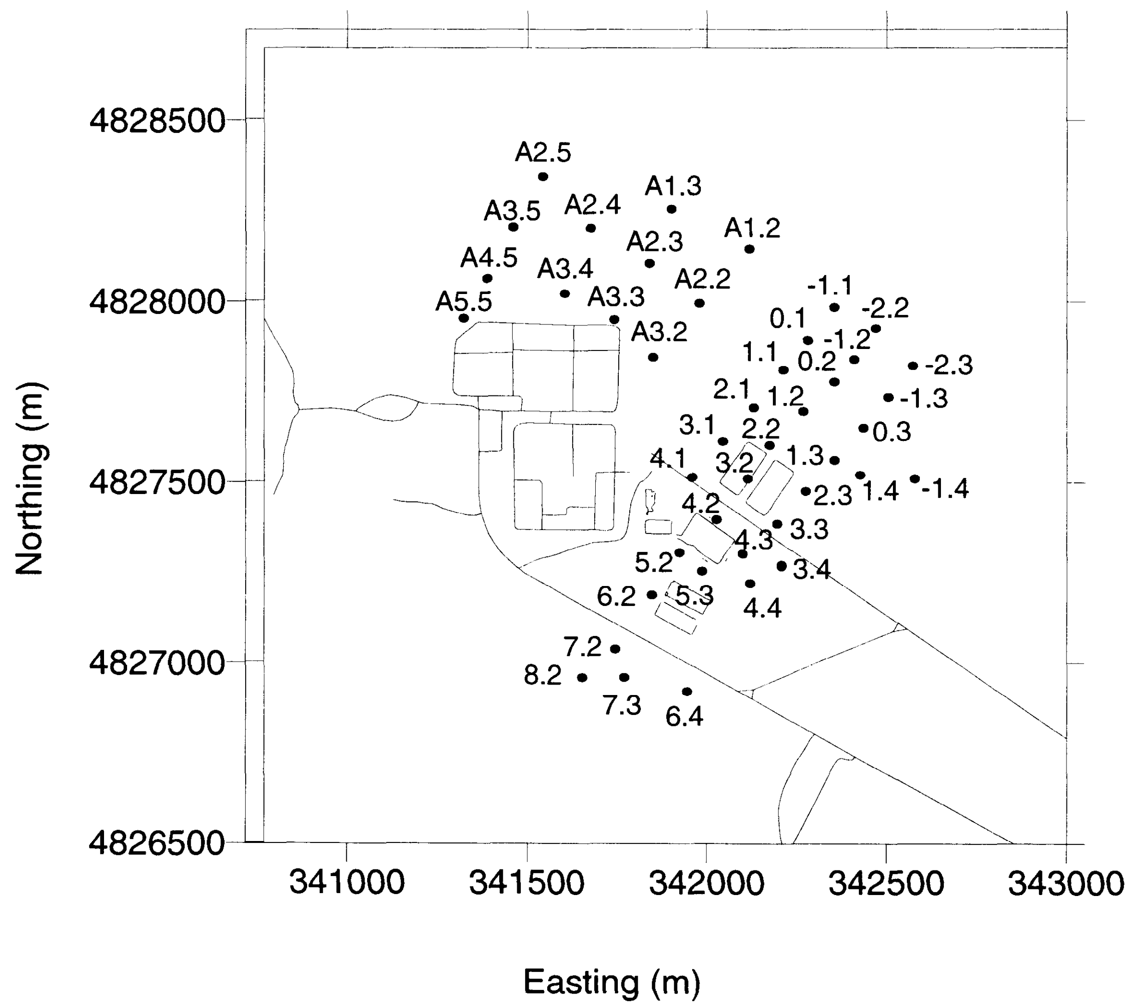

Figure H5-13. RESL soil sampling locations at TRA (adapted from Jessmore et al. 1994).

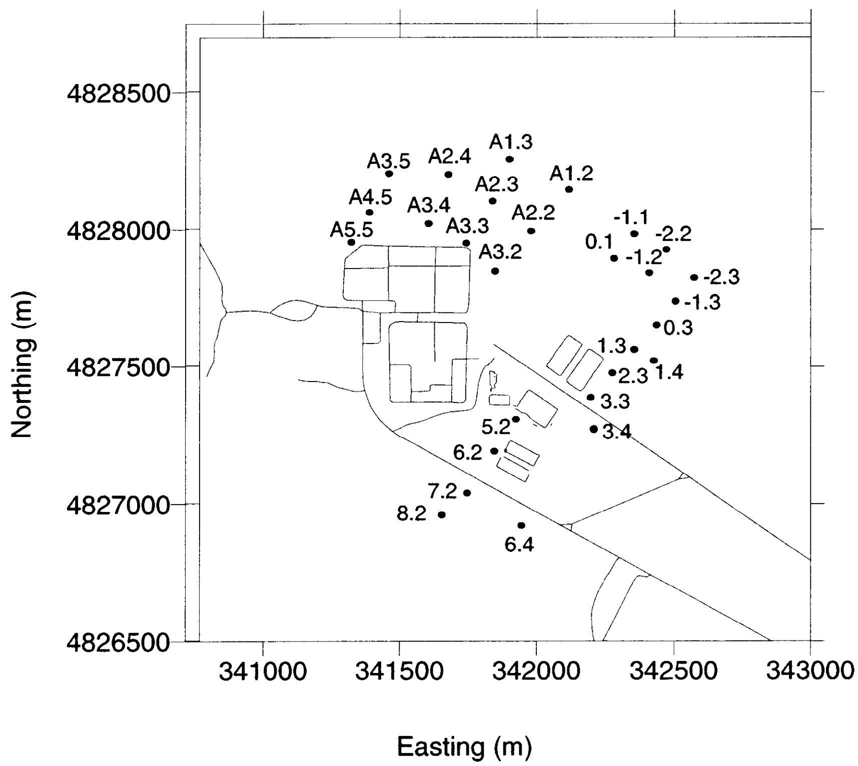

Figure H5-14. ESP soil sampling locations at TRA (adapted from LMITCO 1999).

Soil samples were analyzed for radionuclides using gamma spectroscopy. Cesium-137 was detected above the minimum detection limit in all surface soil samples collected from 0–5 cm (0–2 in.). Other radionuclides were infrequently detected. For this reason, the following discussion focuses on ^{137}Cs.

The results of analyses for ^{137}Cs in the soil samples collected in 1990 and 1997 are shown in Figures H5-15 and H5-16. Figure H5-15 shows that the distribution of ^{137}Cs is not homogeneous, although it does appear to reflect dispersion of contamination in the primary wind direction northeast of the former Warm Waste Pond.

Another contribution to measured concentrations is the background concentration that resulted from historical nuclear weapons testing. Table H5-4 presents background measurements made outside the INEEL by various studies, including one by Martin et al. (1992) and RESL. Rood et al. (1996) also pooled data from studies that used comparable sampling and analytical techniques. Estimates of ^{137}Cs background concentrations range from 0.44 to 0.73 pCi/g. This encompasses some of the measurements made outside the TRA, particularly north of the TRA. On the other hand, the ^{137}Cs concentrations measured northeast and southwest (the primary diurnal directions of wind) of the warm waste ponds show concentrations above background, particularly on the warm waste pond perimeter.

Table H5-4. Background Concentrations of Contaminants in Surface Soil.

Contaminant	Concentration in Surface Soil (pCi/g)		
	Martin et al. (1992)[a]	RESL (1990)[b]	Combined Data
^{60}Co	—	—	—
^{137}Cs	0.53	0.73	0.44[c]
^{90}Sr	—	0.3	0.26[c]
Cr	6.4	N/A	19.4[d]

a. As reported in Rood et al. (1996).
b. As reported in Jessmore et al. (1994).
c. Data sets pooled from RESL and OU 10-6 studies by Rood et al. (1996).
d. Data sets pooled from Martin and NPR studies by Rood et al. (1996).

Figure H5-16 presents results of the 1997 sampling and analyses by the LMITCO Environmental Surveillance Program (ESP). Unfortunately, few samples were collected, and only four samples were collected in the modeled area. The samples collected show one large difference with the previous RESL study performed in 1990. The samples collected at the warm waste perimeter Location 5–2 decreased in ^{137}Cs concentration from 31.8 pCi/g to 0.07 pCi/g. While some decrease can be attributed to radioactive decay, this overwhelmingly reflects the remediation effort conducted in 1993.

Figure H5-17 shows the results of the 1997 LMITCO sampling campaign superimposed on the results of this study. While the measured results appear comparable to the modeled results, it should be noted that the modeled results reflect deposition from remediation activities only and do not include background concentrations. One would have to add from 0.44 to 0.73 pCi/g to the modeled results to reflect background contributions. In addition, the modeled 1964 Cell concentrations (essentially the isopleths from 5 to 24 pCi/g) would have to be discounted as that area was removed and covered with clean fill soil.

Table H5-5 compares the ^{137}Cs concentrations collected at the same locations in 1990 and 1997 with predicted concentrations at those same locations. Because there are only three comparable results, it is difficult to make any concrete conclusions. However, it appears that the remediation was successful in reducing the ^{137}Cs concentration at the pond perimeter (Location 5.2) to a "clean" level. What is not obvious is whether the remediation resulted in increased ^{137}Cs concentrations downwind of the warm waste ponds. It appears that the preremediation concentrations were well above background. This indicates that the downwind area may have been contaminated to levels similar to current concentrations prior to remediation.

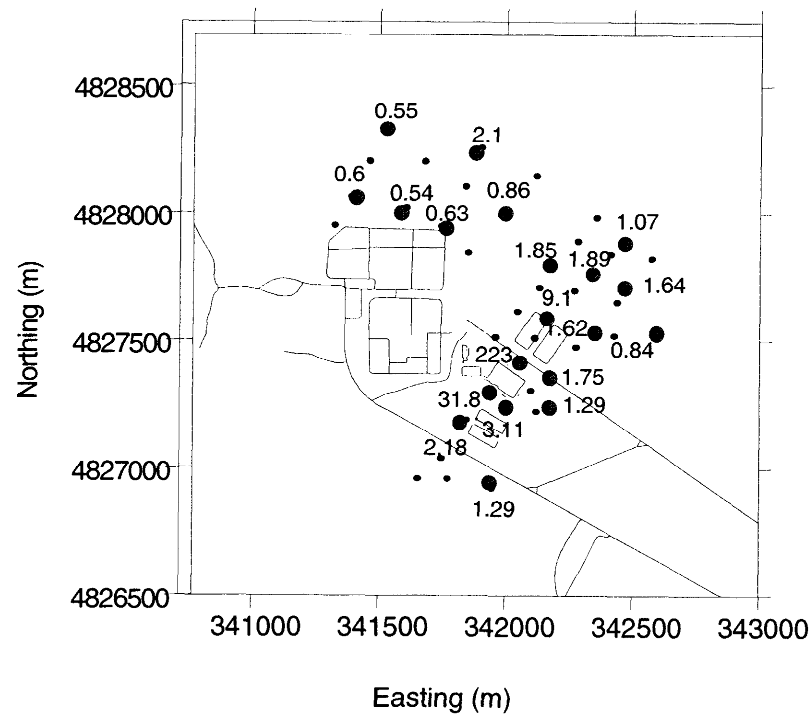

Figure H5-15. Results of analyses of surface soil samples (0–5 cm) collected at select RESL locations in 1990 for ^{137}Cs activity (pCi/g). Sample locations are highlighted in red. (Jessmore et al. 1994).

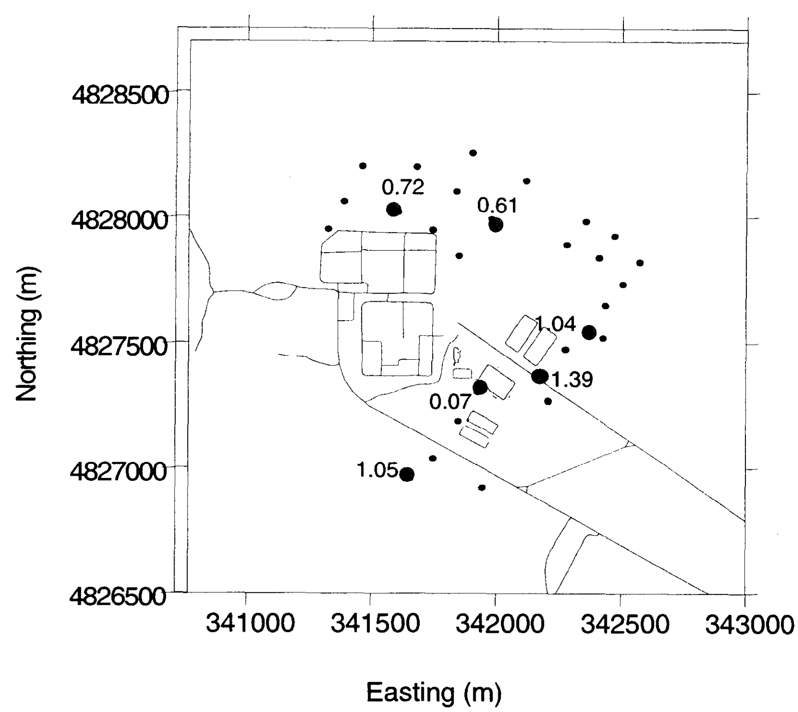

Figure H5-16. Results of analyses of surface soil samples (0–5 cm) collected at select ESP locations in 1997 for ^{137}Cs activity (pCi/g). Sample locations are highlighted in red (LMITCO 1998).

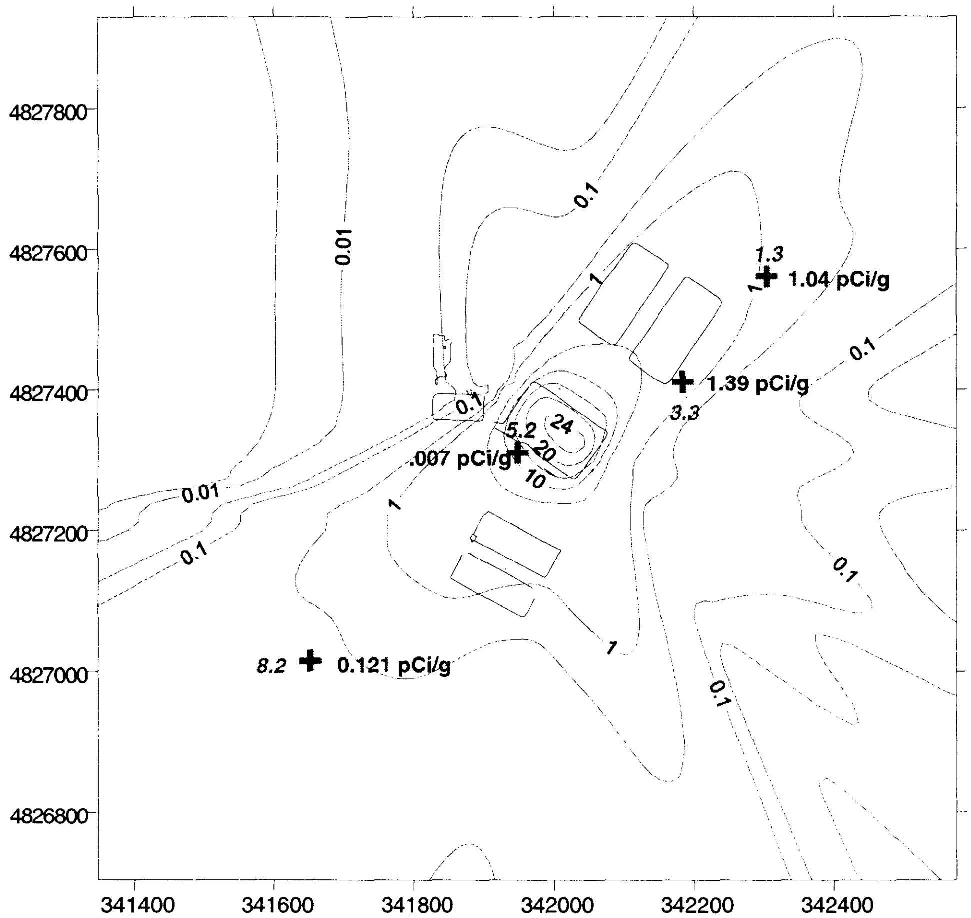

Figure H5-17. Results of ESP analyses for ^{137}Cs of soil samples collected in 1997 (symbolized by crosses) with modeled isopleth results.

Table H5-5. Comparison of measured results with modeled results (pCi/g).

Location	1990 (RESL)[a]	1997 (ESP)[b]	Modeled (2000)[c]
1.3	1.39	1.04	1.14
3.3	1.50	1.39	2.21
5.2	27.19	0.07	21.8

a. From Jessmore et al. (1994). Decayed to 2000.

b. From LMITCO (1998).

c. A background value of 0.44 pCi/g has been added to the modeled result.

H5-4.2.2 1994 TRA Phase II Radionuclide-Contaminated Soil Investigation

In April 1994, 40 surface soil samples were collected at TRA as part of the Operational Unit (OU) 10-06 Phase II radionuclide-contaminated soil investigation for the remedial investigation/feasibility study (RI/FS) (Jessmore et al. 1996). The purpose of the study was to further characterize areas of windblown radionuclide-contaminated soil and to fill existing data gaps. Samples were collected from the 0–10-cm (0–4-in.) depth along transects located in northeast, northwest, southeast, and southwest directions beginning from locations just north and south of the warm waste pond area. The length of the NE, NW, SE, and SW transects (2150 ft, 2800 ft, 2250 ft, and 2675 ft, respectively) was based on radiation isopleths determined by the 1990 areal radiological survey by EG&G Energy Measurements, Inc. (EMI), predominant wind directions, and the RESL sample locations. The transects ended 15 m (50 ft) beyond the outer isopleth determined by the 1990 EMI aerial radiological survey (Figure H5-18). Eleven samples were collected on the NE transect, 12 on the NW transect, and eight each on the SE and SW transects. One sample was also collected at 0° North.

As part of the Phase II investigation, study results were combined with past RESL data (decayed to 1994) and plotted using kriging analysis to determine the extent of contamination. The results are shown in Figure H5-19. Note that there is an area of contamination, which is defined by the kriging t-value boundary, just north of the evaporation ponds and east of the Chemical Waste Ponds. This area was determined to have ^{137}Cs concentrations significantly greater than background. The extent of contamination presented in Figure H5-19 is smaller than the outermost aerial isopleth produced by the 1990 EMI aerial survey and is due, in part, to limitations of the aerial flyover. The estimated areal extent contamination at the TRA Windblown Area was estimated to be 19,230 m^2 (207,000 ft^2), with a vertical extent of 15 cm (6 in.). For this assessment, the background concentration of ^{137}Cs was assumed to be 0.8 pCi/g.

A concentration term for the windblown area was estimated to be 2.4 pCi/g for ^{137}Cs. The concentration term is an estimate of the arithmetic mean, using the 95% upper confidence limit of the arithmetic mean. This value provides 95% confidence that the true site average is not underestimated. The RI/FS concentration term is thus a very conservative estimate because of the way the arithmetic mean was calculated. The total quantity of ^{137}Cs deposited can be estimated using the concentration term of 2.4 pCi/g (minus the background concentration of 0.8 pCi/g), areal extent of contamination (19,230 m^2), depth of contamination (15 cm), and soil density (1.5 g/m^3). The quantity of ^{137}Cs deposited in the Windblown Area from TRA operations (most likely entirely from the Warm Waste Pond) is thus conservatively estimated to be 6.56E-03 Ci. The total source term used in the modeling effort is 1.8E-04 Ci, or about 1/36th of the inventory estimated data from the Phase II study.

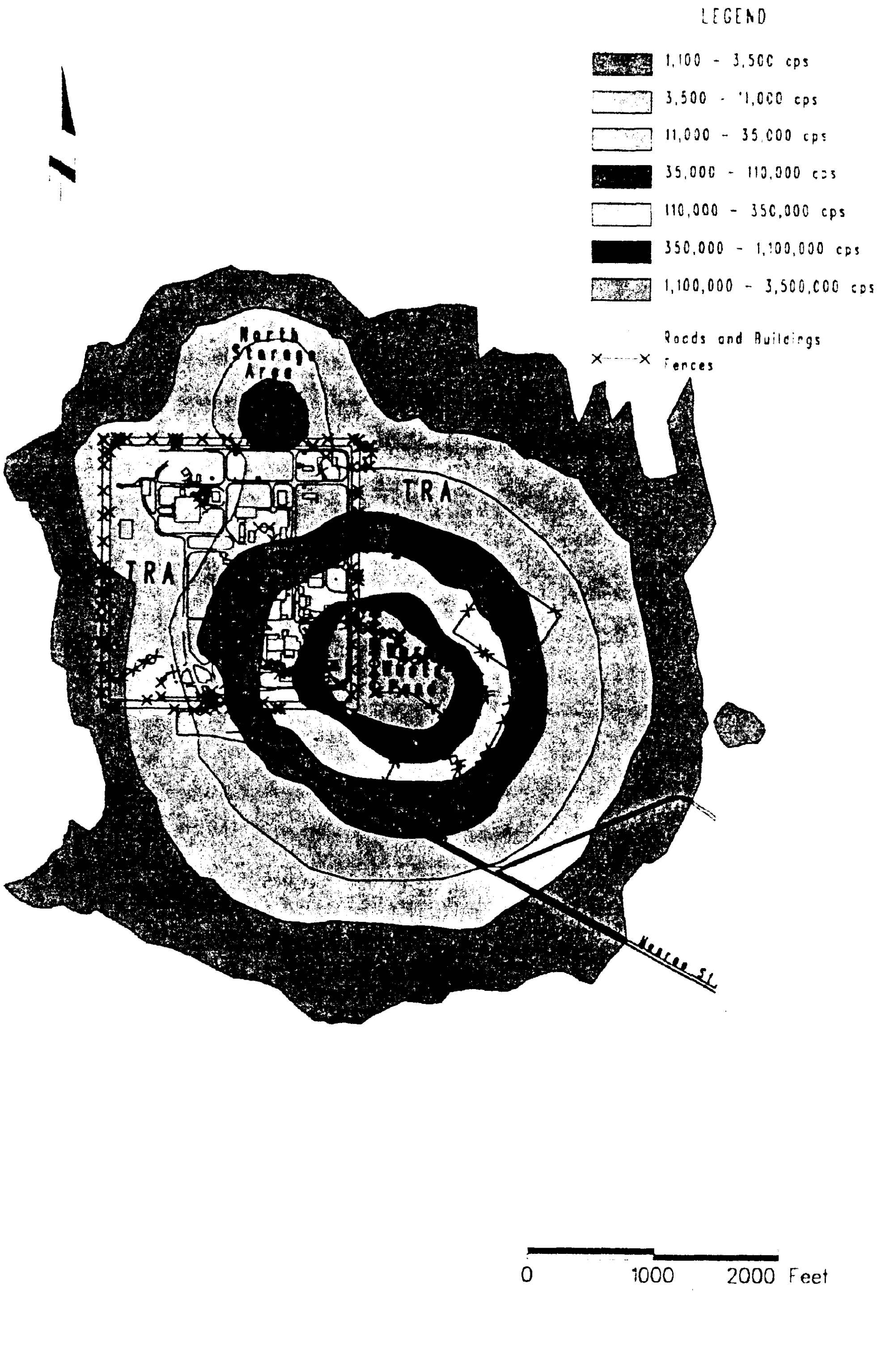

Figure H5-18. Arial radiological survey isopleths, based on 1990 EMI survey (from Jessmore et al. 1996).

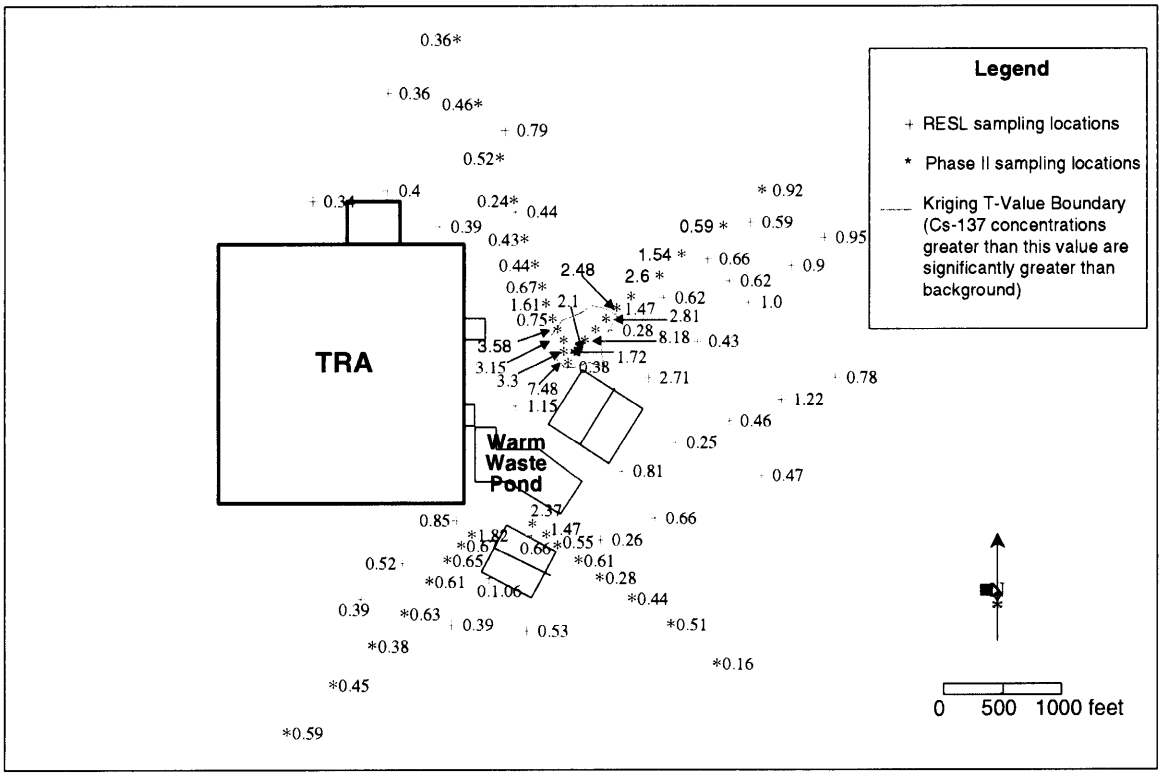

Figure H5-19. OU 10-06 Phase II TRA Windblown Area Sampling and Kriging Results for ^{137}Cs (pCi/g) (Jessmore et al. 1996).

The modeled results (Figure H5-17) appear to show a similar pattern of deposition with the Phase II results. That is, that the concentrations of ^{137}Cs above background primarily occur at locations adjacent to and northeast of the former waste pond. In addition, the modeled results, above background levels, are similar in magnitude to the concentrations measured in the Phase II study. What is not apparent in the modeled results is the area of contamination located north of the evaporation ponds.

H5-4.3 Conclusions

Table H5-4 presents average background concentrations for the contaminants evaluated. Based on these values and Figures H5-8 through H5-12, it can concluded that except in the immediate vicinity of the remediation area, radionuclide concentrations should rapidly decrease to background concentrations downwind of the release source. The modeled chromium concentrations are well below background concentrations, even within the remediation area.

Comparison of modeled results with concentrations of ^{137}Cs measured in the vicinity of TRA by RESL in 1990, by LIMITCO in 1997, and during the OU 10-06 Phase II RI/FS investigation indicate that the predicted downwind concentrations are comparable with existing soil contamination. It appears, however, that some or most of the contamination may not have occurred during the remediation effort. It is possible, but unlikely, that resuspension of sediments during periodic exposure of contaminated sediment could have resulted in the magnitude of deposition observed downwind of the Warm Waste Pond, for reasons discussed in Section 2.1. It is more likely that some other episodic event or series of events that disturbed exposed sediment resulted in the observed amount of deposition. In addition, the Phase II study indicates an additional area of contamination located just north of the current evaporation ponds. The source of contamination is unknown.

For the purpose of the ecological risk assessment, it can be concluded that the extent of wind-blown contamination is limited to the region near and downwind of the Warm Waste Pond. Both modeling and measurements indicate that contaminant concentrations above background values probably do not occur outside that region.

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